RHODORA, Vol. 102, No. 911, pp. 365–372, 2000

NEW ENGLAND NOTE

SNOW ALGAE IN THE NORTHEASTERN U.S.: PHOTOMICROGRAPHS, OBSERVATIONS, AND DISTRIBUTION OF *CHLOROMONAS* SPP. (CHLOROPHYTA)

BRIAN DUVAL

Department of Microbiology, University of Massachusetts,
Amherst, MA 01003
Current Address: Commonwealth of Massachusetts,
Dept. of Environmental Protection,
627 Main St., 2nd floor, Worcester, MA 01608
e-mail: brian.duval@state.ma.us

RONALD W. HOHAM

Department of Biology,
Colgate University, Hamilton, NY 13346
e-mail: rhoham@mail.colgate.edu

Each spring the waters of melting snowpacks revive a unique consortium of microbes and small invertebrates that thrive within this cold oligotrophic environment. While bacteria, fungi, protists, rotifers, tartigrades, and small insects such as Collembola (springtails) all inhabit springtime melting snow (Hoham et al. 1993), snow algae are generally the most conspicuous inhabitants. Populations of snow algae generally manifest as a red, orange, or green color within several centimeters of the snow surface (Hoham 1980; Kol 1968), and they may exceed 10^6 cells ml^{-1} of liquid meltwater (Hoham 1987). In high alpine regions such as in the western United States and in polar regions, expansive blooms of snow algae have been documented and studied extensively with regard to their adaptive capacity to withstand extreme environments (Bidigare et al. 1993; Hoham and Blinn 1979; Hoham and Ling 2000; Thomas 1972; Thomas and Duval 1995). While most studies from North America report snow algae from high alpine areas in the Sierra Nevada, Cascade, and the Rocky mountains, there are relatively few studies that have focused on snow algae from the northeastern United States and Canada (Duval 1993; Dybas 1998; Hoham et al. 1989, 1993).

Snow algae have been described from the White Mountains

(New Hampshire), Green Mountains (Vermont), and the Sunday River ski area and Mt. Katahdin (Maine), as well as the Adirondacks and Tughill Plateau of upstate New York (Duval 1993; Hoham et al. 1993). Snow algae have also been described from the Laurentian Mountains, Quebec (Hoham et al. 1989; Jones 1991), and from southern Ontario (Gerrath and Nicholls 1974), and probably occur in other parts of eastern Canada but have yet to be discovered. In Massachusetts, their occurrence is spotty, limited to the higher elevations of the Berkshire Hills and Wachusett Mountain where there are higher yearly snowfalls or manmade snow (Hoham et al. 1993). There are no reports of snow algae from southern New England or the middle or southern Appalachian ranges. A reconnaissance to the West Virginia highlands found no evidence of snow algae in melting spring snow (Duval, unpubl. data).

From our studies between 1972–1998, we plotted locations where snow algae were and were not found in the northeastern United States. These findings were compared to a snowfall accumulation map compiled by the Northeast Regional Climate Center (Cember and Wilks 1993), and the results are shown in Figure 1. The snow depth lines are for an "average winter," i.e., in the 50th percentile. Our records show that in the northeastern United States, areas with greater than 200 cm (80 in.) of annual snowfall are more likely to have snow algae than areas that receive lesser snowfall amounts. However, contrary to this generalization is a lack of positive snow algal findings from West Virginia, many parts of the central plateau of New York State, and wooded areas near the city of Syracuse, all of which receive greater than 200 cm of snowfall annually. Thus, snow algal distribution probably involves other factors in addition to snowfall accumulation such as vegetative habitat, the rate at which snowpacks melt, or physio-chemical aspects that affect snow on a regional level (Hoham et al. 1989; Jones 1991).

In the northeastern United States, populations of green snow algae (Figure 2), are typically found in the shaded coniferous fir and spruce forests at high elevations (Hoham et al. 1989). Here, to avoid misnaming the species shown in Figure 3, earlier described as *Scotiella cryophila* and later as a resting spore of *Chloromonas nivalis,* we refer to the spindle-shaped resting spore as *Chloromonas* sp.-A. We hope that a later explanation and Latin

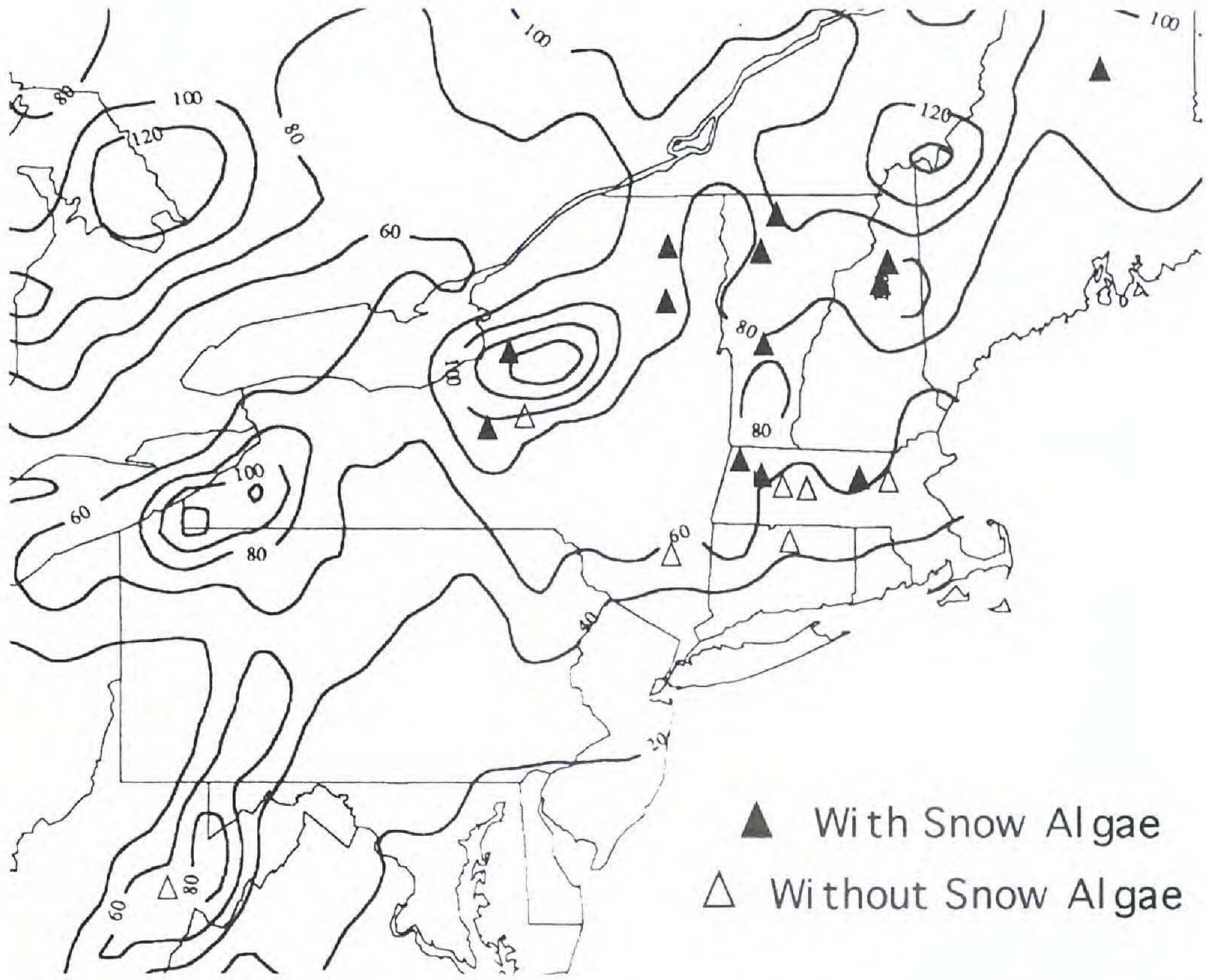


Figure 1. Map of snow algal distribution in the northeastern United States shown with average yearly snowfall accumulation.

description will help clarify the confusion surrounding the name of this snow alga.

Additionally, we have observed a species of salmon-orange colored snow alga in open areas from several New England ski areas (Duval 1993; Hoham et al. 1993). Since we have observed only a few biflagellate cells that appear to belong to *Chloromonas,* we designated the species as *Chloromonas* sp.-B until further observations are made (Hoham et al. 1993). We have found *Chloromonas* sp.-B to inhabit snow at four disjunct ski areas in New England and have not observed this alga in natural alpine snow. This has led us to propose that one of the mechanisms of this snow alga's dispersal might involve transport of resting spores on the bottom of skis (Dybas 1998; Hoham et al. 1993).

Morphologically, the resting stage of *Chloromonas* sp.-B is oval to rounded, ranges in size between 10–25 μm in diameter (Figure 4), has an outer wall about 1 μm thick (Figure 5), and resembles resting stages reported for other species of *Chloromonas* (Hoham 1975; Hoham and Mullet 1978; Hoham et al.

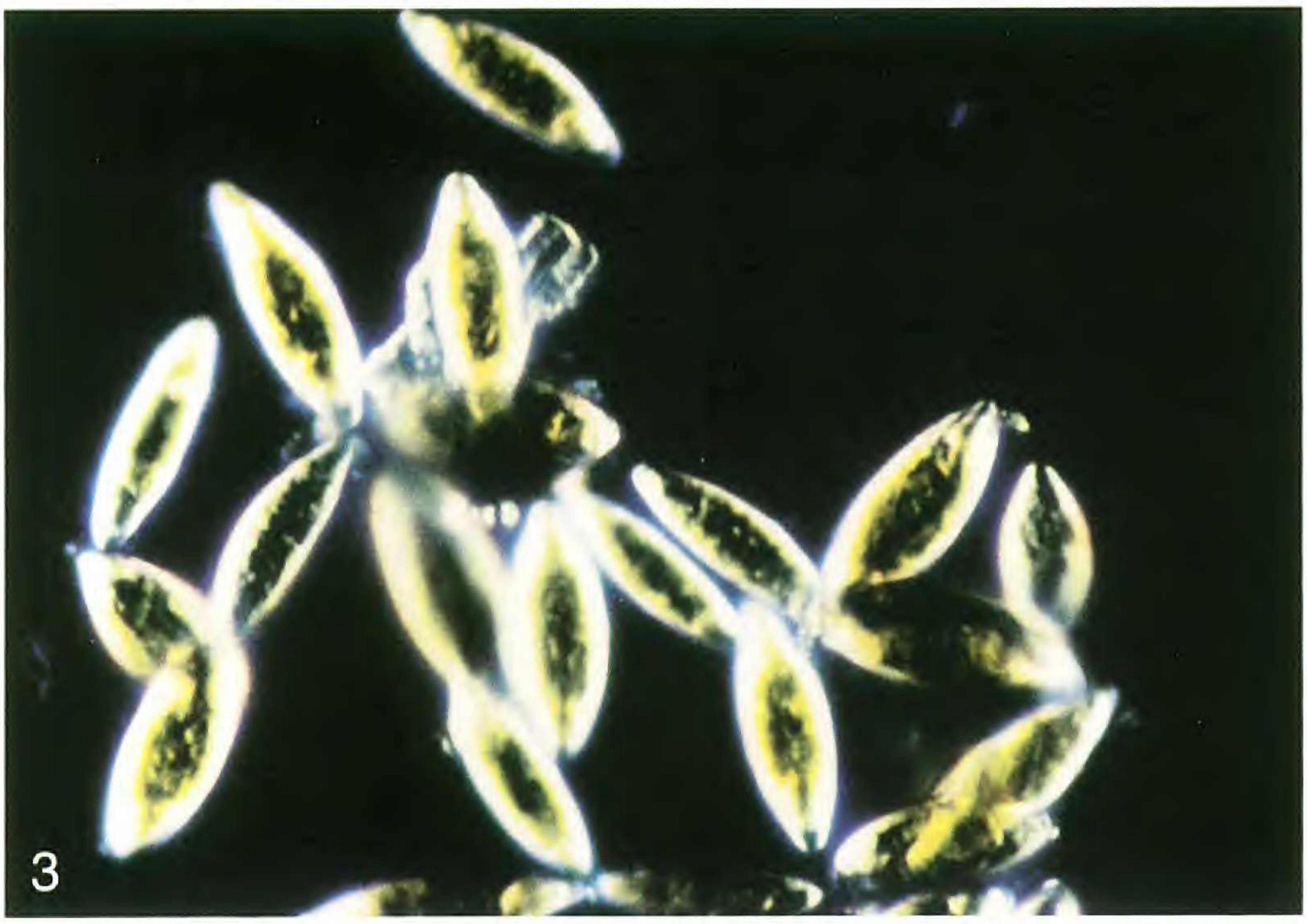
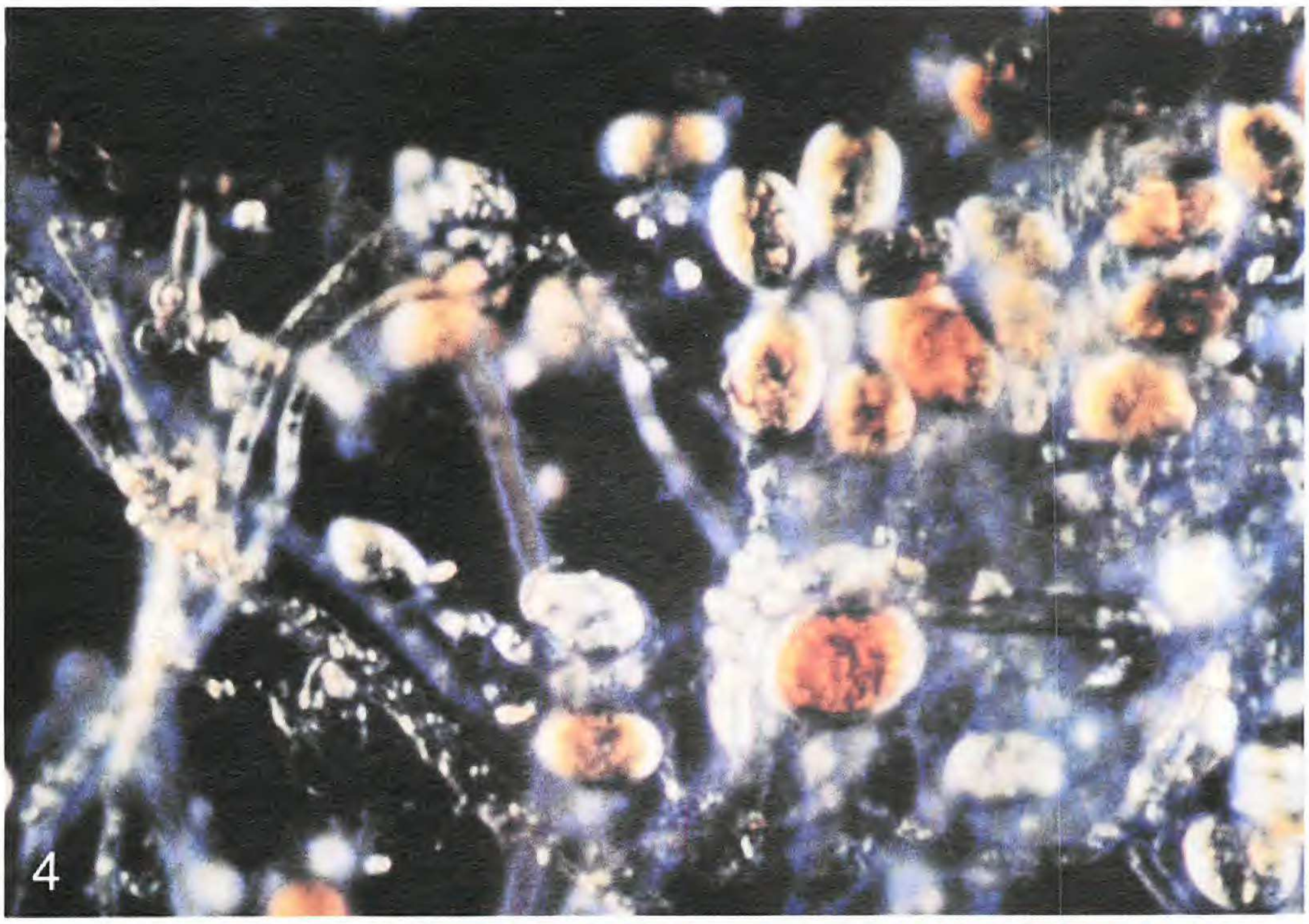


Figure 2. A green population of *Chloromonas* snow algae from Mt. Washington, New Hampshire. In North America, populations of green snow algae are found near the snow surface in shaded areas such as in coniferous forests.

Figure 3. Spindle-shaped asexual resting spores of *Chloromonas* sp.-A green snow algae found in the New York Adirondacks and New England, photographed at 400 × magnification using Nomarski interference contrast optics (DIC). These algae are from a population collected from the Berkshire Hills, Massachusetts.



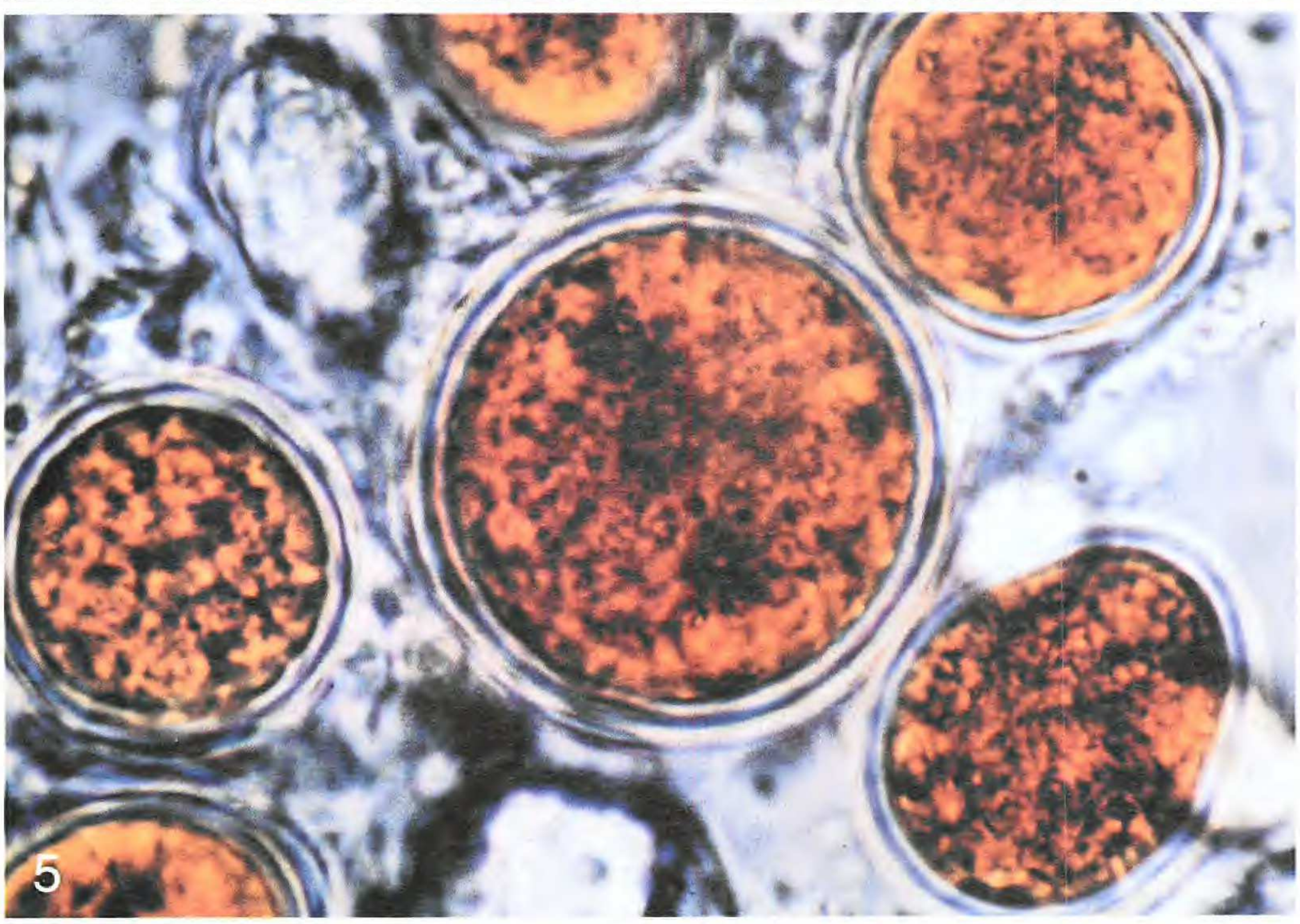


Figure 4. The salmon-orange colored snow alga designated as *Chloromonas* sp.-B (Hoham et al. 1993) collected from the ski area at Killington Peak, Vermont. Filamentous fungi are generally in close proximity to, or in contact with the algae (200 ×).

Figure 5. *Chloromonas* sp.-B snow algal resting spores at 1000 × magnification. Note the differences in cell size, shape, and the 1 μm thick wall that envelopes each cell.

1983). *Chloromonas* sp.-B is generally observed with filamentous fungi and often appears to be in contact with them. However, while fungi and snow algae are generally observed together in snow samples, it is not clear if there is any exchange of nutrients or other symbiosis-like relationship between the two microbial types.

The difference in habitat between species of snow algae, i.e., the green *Chloromonas* sp.-A under forest canopy and the orange pigmented *Chloromonas* sp.-B found in open areas, has previously been observed and attributed to variations in light intensity (Fukushima 1963). *Chloromonas* sp.-B is orange in color due to intracellular carotenoids and other pigments that may serve as photoprotectants toward biologically harmful ultraviolet radiation (Bidigare et al. 1993; Czygan 1970; Thomas and Duval 1995). Indeed, the absorption spectra from solvent extractions of this alga show absorption in the visible wavelength regions typical of chlorophylls and carotenoids, as well as in the ultraviolet regions (Duval 1993).

Chloromonas sp.-B is often observed at the snow surface near shoots of sprouting *Cornus* sp. (dogwood), *Acer pensylvanicum* (striped maple), and *Betula alleghaniensis* (yellow birch), and occasionally it is found at a depth of 5–10 cm, coloring the snow salmon-orange. This species and other snow algae consistently appear at the end of the snow melt period (April–May) in areas where deep snow tends to accumulate from year to year. It is interesting to note that at lower elevations (Tughill Plateau and Georgetown Hill, New York), snow algae have been found in ravines where enough snow accumulates to allow for a deeper snowpack. *Chloromonas* sp.-B generally appears near the snow surface in late April and May, but has been collected as late as July from Tuckerman Ravine, Mt. Washington, New Hampshire. Algal predators such as rotifers and ciliated protists are often observed within snow samples and are members of the snowpack ecosystem that can support several levels of microbial diversity (Hoham and Duval 2000; Hoham et al. 1993).

It is our intention to stimulate the amateur microbial ecologist through the photographs presented here to investigate melting snowpacks, which provide an ephemeral microbial ecosystem within their cold meltwaters.

ACKNOWLEDGMENTS. Our thanks to Dr. Lynn Margulis, University of Massachusetts, Amherst, for the use of her laboratory and microscopy equipment, Colgate University for laboratory and library facilities, and the University of Massachusetts Biological Science Library.

LITERATURE CITED

BIDIGARE, R. R., M. C. KENNICUTT II, R. ITURRIAGA, H. R. HARVEY, R. W. HOHAM, AND S. A. MACKO. 1993. A photoprotective function for secondary carotenoids of snow algae. J. Phycol. 29: 427–434.

CEMBER, R. P. AND D. S. WILKS. 1993. Climatological Atlas of Snowfall and Snow Depth for the Northeastern United States and Canada. Northeast Regional Climate Center Research Series, Cornell University. Publ. # RR 93–1, Map 49.

CZYGAN, F. C. 1970. Blutregen und Blutschnee: Stickstoffmangel-Zellen von *Haematococcus pluvialis* und *Chlamydomonas nivalis*. Arch. Mikrobiol. 74: 69–76.

DUVAL, B. 1993. Snow algae in northern New England. Rhodora 95: 21–24.

DYBAS, C. 1998. Alga rhythms. Adirondack Life 29: 21–24.

FUKUSHIMA, H. 1963. Studies on cryophytes in Japan. J. Yokohama Munic. Univ., Ser. C, Nat. Sci. 43: 1–146.

GERRATH, J. F. AND K. H. NICHOLLS. 1974. A red snow in Ontario caused by the dinoflagellate, *Gymnodinium pascheri*. Canad. J. Bot. 52: 683–685.

HOHAM, R. W. 1975. The life history and ecology of the snow alga *Chloromonas pichinchae* (Chlorophyta, Volvocales). Phycologia 14: 213–226.

———. 1980. Unicellular Chlorophytes-Snow Algae, pp. 61–84. *In:* E. R. Cox, ed., Phytoflagellates. Elsevier/North Holland, New York.

———. 1987. Snow algae from high-elevation, temperate latitudes and semipermanent snow: Their interaction with the environment, pp. 73–80. *In:* J. Lewis, ed., Proc. 44th Annu. Eastern Snow Conf., Fredericton, NB, Canada.

——— AND D. W. BLINN. 1979. Distribution of cryophilic algae in an arid region, the American Southwest. Phycologia 18: 133–145.

——— AND B. DUVAL. 2000. Microbial ecology of snow and fresh-water ice with emphasis on snow algae, pp. 166–266. *In:* H. G. Jones, J. W. Pomeroy, D. A. Walker, and R. W. Hoham, eds., Snow Ecology: An Interdisciplinary Examination of Snow-covered Ecosystems. Cambridge Univ. Press, Cambridge, UK.

———, A. E. LAURSEN, S. O. CLIVE, AND B. DUVAL. 1993. Snow algae and other microbes in several alpine areas in New England, pp. 165–173. *In:* M. Ferrick and T. Pangburn, eds., Proc. 50th Annual Eastern Snow Conf., Quebec City, Canada.

——— AND H. U. LING. 2000. Snow algae: The effects of chemical and physical factors on their life cycles and populations. *In:* J. Seckbach, ed., Microbial Diversity. Klewer Press, The Netherlands (in press).

——— AND J. E. MULLET. 1978. *Chloromonas nivalis* (Chod.) Hoh. & Mull. comb. nov., and additional comments on the snow alga, *Scotiella*. Phycologia 17: 106–107.

———, ———, AND S. C. ROEMER. 1983. The life history and ecology of the snow alga *Chloromonas polyptera* comb. nov. (Chlorophyta, Volvocales). Canad. J. Bot. 61: 2416–2429.

———, C. P. YATSKO, AND H. G. JONES. 1989. Recent discoveries of snow algae in Upstate New York and Quebec Province and preliminary reports on related snow chemistry, pp. 196–200. *In:* J. Lewis, ed., Proc. 46th Annual Eastern Snow Conf., Quebec City, Canada.

JONES, H. G. 1991. Snow chemistry and biological activity: A particular perspective on nutrient cycling, pp. 173–228. *In:* T. D. Davies, M. Tranter, and H. G. Jones, eds., NATO ASI Series G: Ecol. Sci., Vol. 28, Seasonal Snowpacks, Processes of Compositional Changes. Springer-Verlag, Berlin.

KOL, E. 1968. Kryobiologie. Biologie und Limnologie des Schnees und Eises. I. Kryovegetation, pp. 1–216. *In:* H. J. Elster and W. Ohle, eds., Die Binnengewasser. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

THOMAS, W. H. 1972. Observations on snow algae in California. J. Phycol. 8: 1–9.

——— AND B. DUVAL. 1995. Sierra Nevada, California, U.S.A., snow algae: Snow albedo changes, algal-bacterial interrelationships, and ultraviolet radiation effects. Arctic Alpine Res. 27: 389–399.